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CLOUD PARAMETERS DERIVED FROM GOES DURING THE 1987 MARINE STRATOCUMULUS FIRE INTENSIVE FIELD OBSERVATION PERIOD

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1. Introduction

The Geostationary Operational Environmental Satellite (GOES) is well suited for observations of the variations of clouds over many temporal and spatial scales. For this reason, GOES data taken during the Marine Stratocumulus Intensive Field Observations (IFO) (June 29 - July 19, 1987, Kloessel et al., 1988) serve several purposes. One facet of the First ISCCP Regional Experiment (FIRE) is improvement of our understanding of cloud parameter retrievals from satellite-observed radiances. This involves comparisons of coincident satellite cloud parameters and high resolution data taken by various instruments on other platforms during the IFO periods. Another aspect of FIRE is the improvement of both large- and small-scale models of stratocumulus used in general circulation models (GCMs). This may involve, among other studies, linking the small-scale processes observed during the IFO to the variations in large-scale cloud fields observed with the satellites during the IFO and Extended Time Observation (ETO) periods. This paper presents preliminary results of an analysis of GOES data covering most of the IFO period. The large-scale cloud-field characteristics are derived, then related to a longer period of measurements. Finally, some point measurements taken from the surface are compared to regional scale cloud parameters derived from satellite radiances.

2. Data and methodology

The data used in this study are hourly GOES-East, 8-km visible (0.65 μm) and infrared (10.5 μm) radiances and half-hourly GOES-West 1-km visible and 4-km infrared radiances. Analysis of the data is the same as that described by Minnis et al. (1988). The cloud parameters were derived for 2.5° regions between 140°W and 115°W longitudes and 40°N and 25°N latitudes. They include cloud amount, cloud-top temperature, cloud albedo, and clear-sky temperature and albedo for each region. All of the cloud parameters were derived for total, low (< 2 km), middle (2-6 km), and high (> 6 km) clouds. GOES-East cloud amounts were corrected for viewing zenith angle as described by Minnis et al. (1988). Albedo here refers to the mean top-of-the-atmosphere broadband shortwave (0.2 - 5.0 μm) albedo over clear or cloudy areas. Details of its determination from the visible radiances are given in Minnis et al. (1988). Means are computed in the same fashion noted by Minnis et al. (1987).

3. Large-scale cloud features

At the time of this writing, only the cloud analyses from a 3-hourly subset of the July, 1987 GOES-East data were completed. All results shown here refer to July 2-19, 1987 GOES-East data, unless specified otherwise. Mean total cloudiness, shown in Fig. 1a, is less than 70% along the California coast reaching a maximum of more than 90% near 34°N and 132°W.

Total cloudiness is < 70% in the southeastern and southwestern corners of the grid. Except over land areas and the northwestern corner, more than 95% of the total cloud cover consists of low-level clouds (Fig. 1b).

The clear-sky temperatures (Fig. 2) over the ocean range from about 285K in the north to 290K in the southeastern corner of the region. Mean oceanic, equivalent blackbody, cloud-top temperatures in Fig. 3 vary from 276K in the northwestern corner to about 286K in the southeastern corner. Mean clear ocean albedos range between 0.10 and 0.12 while cloud albedos (Fig. 4) over the ocean regions are between 0.30 and 0.40. Maximum cloud albedos occur within much of the IFO region southwest of Los Angeles. Minimum cloud albedo (0.31) occurs over the southeastern and southwestern corners of the region.

Diurnal variability of total cloud cover is plotted in Fig. 5 for each 2.5° region. Maximum cloudiness occurs around 0600 LT over all of the ocean regions while the minimum is found during the afternoon. Two large areas assumed to represent near-coast and midocean conditions are defined as the pacific (PAC) region between 25°N and 32.5°N and 140°W and 132.5°W and the IFO region bordered by 35°N and 30°N and 125°W and 120°W with an additional 2.5° region to the east centered at 31.3°N and 118.8°W. The 3-hourly means for these two regions are shown in Fig. 6. Maximum cloudiness occurs at the same time for both of these regions, while minimum cloudiness appears to occur earlier over the PAC than it does over the IFO region. The diurnal range over the PAC is significantly higher than over the IFO region.

Although cloud amounts during the 18-day period are from 0 to 20% greater than the July 2-31 mean value, the remaining parameters are very close to the corresponding monthly means. These results appear to be relatively typical of the cloud properties observed over this same grid during earlier years. A comparison with the data of Minnis et al. (1988) reveals very similar patterns in cloud-top temperature, cloud albedo, clear-sky temperature, cloud amounts, and diurnal cloud variability. The slightly lower values of cloud albedo may be due to uncertainties in the calibration procedures. The extreme viewing zenith angles in these data may also affect some of the parameter values. Despite these potential limitations, these results indicate that the IFO period represents fairly typical conditions over the California marine stratocumulus region.

4. Comparisons with surface observations

Most of the comparisons with other analyses will attempt to match the spatial domain of the correlative data to a reasonable degree. In this section, however, point measurements of cloud properties taken from San Nicolas Island are compared to large-area averages derived from the GOES results over a 2.5° region, designated R39, centered at 31.3°N and 118.8°W which is just south of the island. (The region containing the island is partially land-covered, introducing some complications). This comparison is shown to demonstrate how the surface and/or aircraft data may be related to the satellite cloud retrievals. The point measurements are the values of cloud-top height and cloud base, cloud liquid water density, and solar irradiance measured between 1200 UT July 12 and 0600 UT July 15 as well as the hourly averages of liquid water for July 2-19, 1987 (FIRE, 1987).

Figure 7 shows the time series of cloud cover over R39, while the corresponding clear-sky and cloud-top temperatures are given in Fig. 8 with the San Nicolas Island cloud base and top heights. Clear-sky temperature changes by less than 1K over the period. Cloud-top temperature and cloud-top altitude vary in a negative correspondence. Significant breaks in the

clouds over the island also occur during the lowest cloud amounts over R39 late on July 12 and early on July 13. The values of cloud albedo shown in Fig. 9 reveal sparse sampling, but also vary with the liquid water density over the island. Cloud albedo normally increases with increasing solar zenith angle because of increased air mass. If the cloud properties are constant, then the cloud albedo variation should be symmetrical about local noon and the same each day. Local noon occurs at approximately 1955 UT. Thus, aside from the increasing albedo from July 12 to July 14, a morning bias in cloud albedo is also evident. These two patterns apparently reflect the variations in cloud liquid water density. This correspondence is clearer in the comparison of the 18-day means of albedo and liquid water which show a morning bias in both quantities (Fig. 10). Similar cloud albedo variations have been reported over other regions covered by large-scale stratocumulus cloud fields (e.g., Minnis and Harrison, 1984). Eighteen-day averages of cloud amount and cloud-top temperature (Fig. 11) also suggest that the variations in stratocumulus cloud properties seen during this small window are fairly representative of the clouds in this area during July.

5. Concluding remarks

The preliminary results presented here have led to several conclusions. It appears that the large-scale cloud properties observed during the 1987 IFO are very similar to the climatological (i.e., 1984-1987) means. Thus, the results of this experiment should be very representative of the California marine stratocumulus during July. Regional-scale satellite measurements appear to correspond closely to island-observed quantities suggesting that the island observations are representative of cloud property variations on a much larger scale. These results also indicate that the satellite retrieval is producing a reasonable estimate of stratocumulus characteristics. Much additional research is anticipated using the GOES-West satellite with higher temporal and spatial sampling. This should allow for improvements in defining cloud structure and in matching the satellite observations to those on other platforms.

6. References

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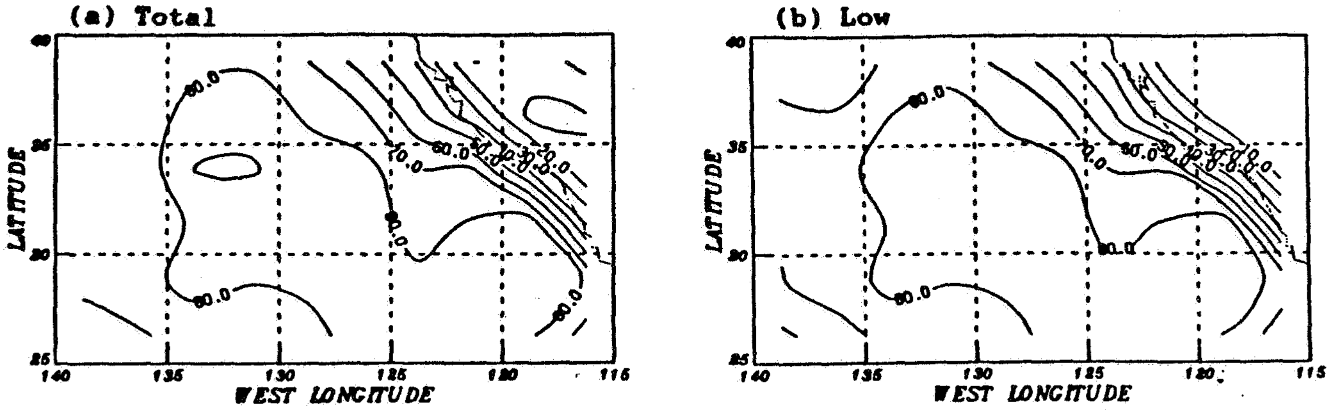

Figure 1. Mean cloud amounts (%) for July 1987.

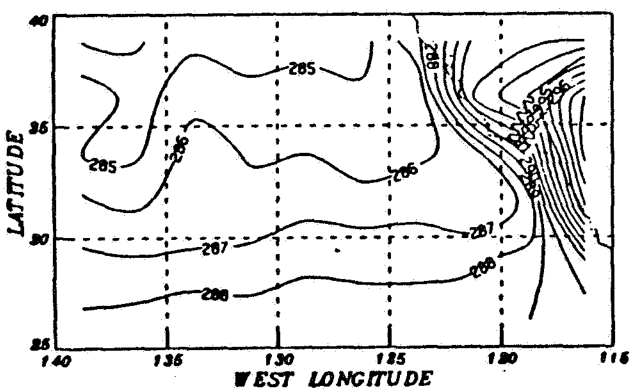

Figure 2. Mean clear-sky temperatures for July 1987.

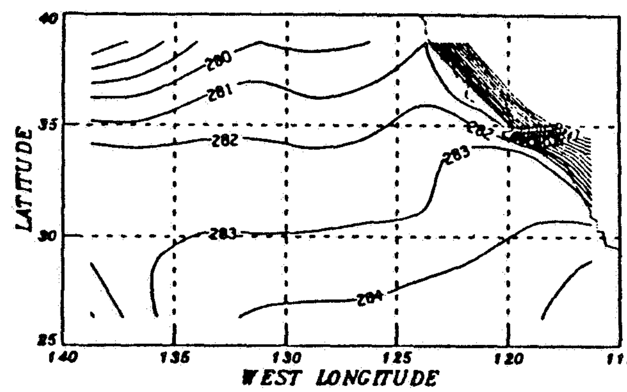

Figure 3. Mean cloud-top temperatures for July 1987.

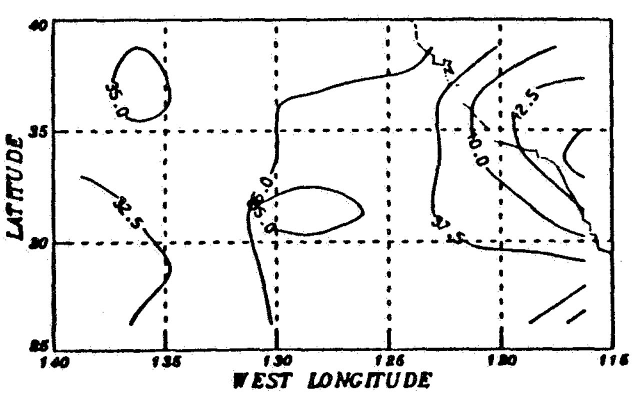

Figure 4. Mean cloud albedo (%) for July 1987.

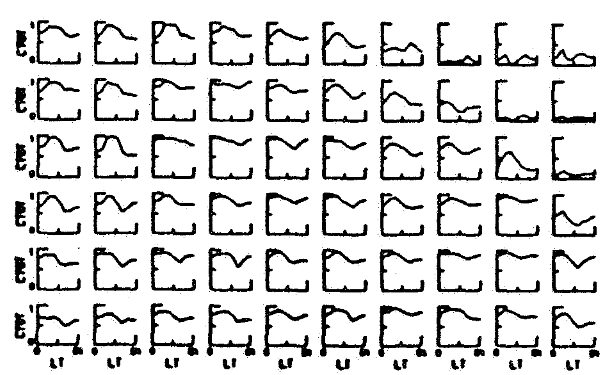

Figure 5. Diurnal variability of total cloud amount (%).

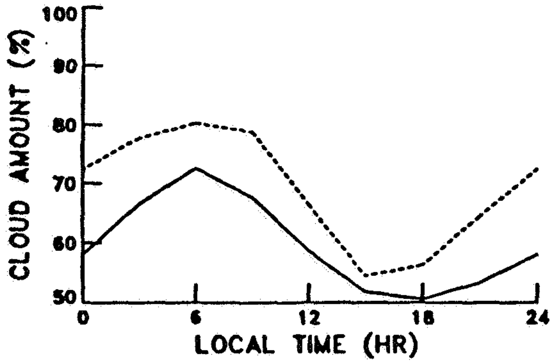

Figure 6. Diurnal variability of total cloud amount (%) for the IFO and PAC regions.

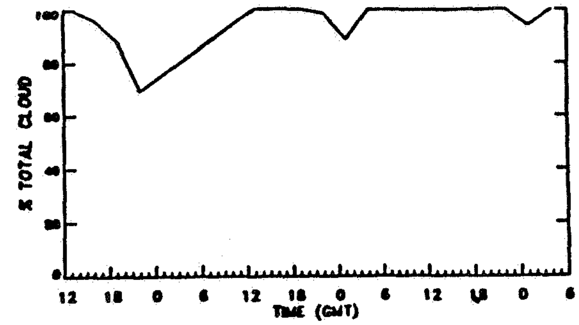

Figure 7. July 12-14 time series of Region 39 cloud amount (%).

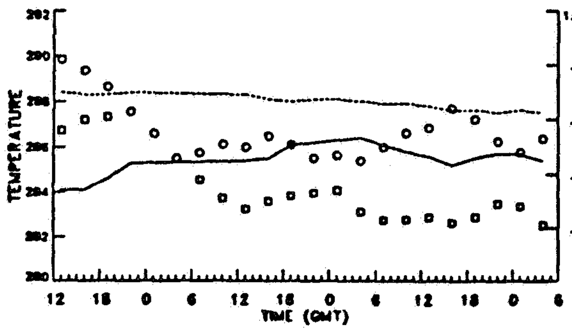

Figure 8. July 12-14 time series of clear (......) and cloud (——) temperature with San Nicolas cloud top (○) and base (□) height.

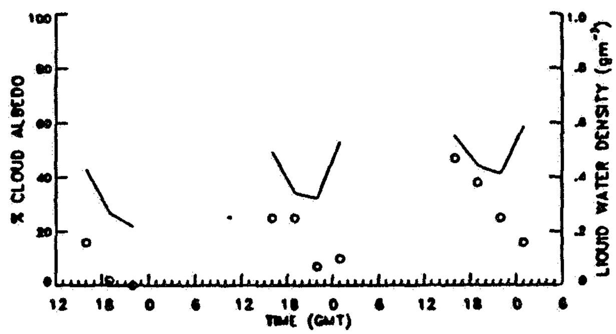

Figure 9. July 12-14 time series of cloud albedo (——) over Region 39 with San Nicolas LWD (○).

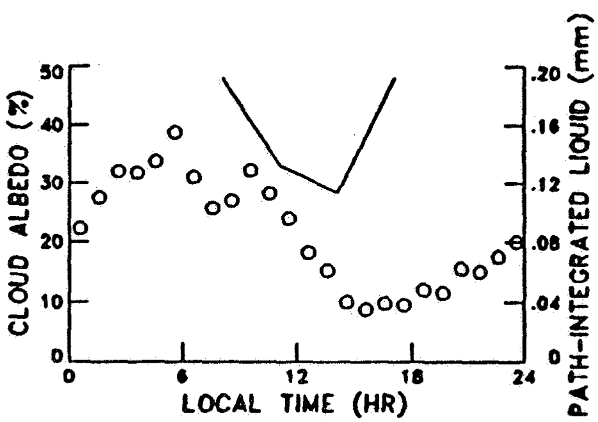

Figure 10. 18-day mean cloud albedo over Region 39 and San Nicolas lwc (○).

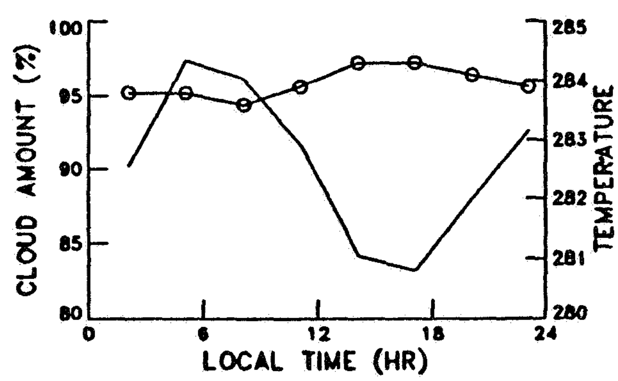

Figure 11. 18-day mean cloud amount (——) and cloud-top temperature (-⊖-) over Region 39.